BELLCOMM, INC.
955 L'ENFANT PLAZA NORTH, S.W. WASHINGTON, D. C. 20024

B70 12080

SUBJECT: Space Shuttle Descriptions For Operations Support Systems Study - Case 900

DATE: December 31, 1970

FROM: D. E. Cassidy

ABSTRACT

This memorandum contains a description of the Space Shuttle which was used in the Operations Support System Study made by Bellcomm for the Office of Manned Space Flight. The Space Shuttle as described is representative of the NASA's current concepts of a two stage fully reusable launch and reentry system as they are being defined by the Phase B definition studies underway at North American Rockwell and the McDonnell Douglas Aerospace Company. The description includes the baseline system characteristics, mission characteristics, trajectory characteristics and flight profile, and a reference mission model.

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MEMORANDUM FOR FILE

1.0 INTRODUCTION

Bellcomm has undertaken an Operations Support System study (OSS), at the request of the Director of Missions Operations, OMSF, to investigate a method of conducting manned space operations in the post-1975 era that is different from the method presently employed by the NASA.[1] The existence of new space systems such as a manned permanent space station and a fleet of space shuttle earth to orbit transportation vehicles will affect current launch and space operations. The study is intended to identify and analyze the major operational systems and functions anticipated for this period from the view-point of a Centralized Operations Center.

The purpose of this memorandum is to provide a description of the Space Shuttle system which can be used in the Bellcomm OSS study. The Space Shuttle system described here is subject in time to continuous changes in operational concept and systems design, and at best can only reflect the current NASA thinking. The general characteristics, weights and sizes presented in this memorandum are representative of the systems under study in the two Phase B definition studies,[2,3,4,5] and are reasonably consistent with the NASA Phase B Statement of Work,[6] and the Space Shuttle Program Requirements Document, Level 1 as of September 1, 1970 (see Appendix). The Space Shuttle as currently conceived could be considered an ideal or full capability system so it should be recognized that some of the concepts such as autonomy, minimum refurbishment and operational flexibility might not be achieved with the initial development vehicles.

2.0 BASELINE SPACE SHUTTLE SYSTEM CHARACTERISTICS

2.1 Vehicle Configurations

The Space Shuttle is a two stage fully reusable launch and reentry vehicle. The two stages (Orbiter and Booster) are launched in the vertical position with the Orbiter attached to the top of the Booster (piggyback) and landed separately on a horizontal runway in a manner similar to aircraft. The representative Space Shuttle Orbiter and Booster configurations chosen for the OSS study are illustrated in Figure 1, and are based on the North American Rockwell high cross range design.[5] The system weights were increased from the reference design to account for the change to JP4 fuel for the airbreathing engines as noted by item 23 in the appendix. These configurations reflect the current Space Shuttle concept and should provide a convenient and representative set of numbers.

An alternative Shuttle Orbiter design employing fixed straight wings is also under investigation in the NASA Phase B studies for missions which do not require high cross range during reentry. However, since the requirement for high cross range has been identified for certain Department of Defense missions, the delta winged orbiter was chosen for the OSS study. The straight wing orbiter is illustrated in Figure 2 for comparison with the reference delta winged orbiter.

The Orbiter and Booster each have a two man crew during all phases of the mission and all flight operations are under the control of the crew. In addition to the crew, the orbiter can carry a life support module for 12 passengers for up to 7 days which can be extended to 30 days by carrying the necessary expendables at the expense of payload. The maximum load factor on the Orbiter passengers will not exceed 3 g during either ascent or descent and the cabin environment in both the Orbiter and Booster will permit personnel to function without the need for spacesuits.

The Space Shuttle Orbiter contains a cylindrical payload compartment with a clear volume 60 feet long and 15 feet in diameter. The payload weight is mission dependent and will be discussed later. The payload compartment is nominally unpressurized for unmanned payloads but is capable of accepting a pressurized manned laboratory for short duration manned orbital missions and pressurized storage tanks for propellant delivery. An airlock and passageway connects the manned compartment with the payload compartment allowing on-orbit operations to be conducted intra-vehicularly (IVA). Personnel and cargo will nominally be transferred to the Space Station through airlocks connecting the Orbiter to the Space Station.

The reference Shuttle lift-off weight of 3,980,000 pounds includes 3,330,000 pounds for the Booster and 650,000 pounds for the Orbiter including payload. The Orbiter and Booster vehicles are stressed to support these weights only while in the vertical position on the launch pad. The maximum static weights in the horizontal position with landing gears extended are about 209,500 pounds for the Orbiter including the payload, 480,000 pounds for the Booster alone, and 689,500 pounds for the Booster with the Orbiter attached. The total liquid hydrogen load consumed by all the Orbiter and Booster systems for each mission is about 457,000 pounds not including boil-off losses during propellant loading and countdown. The total liquid oxygen load is about 2,740,000 pounds.

2.2 Systems Operation and Autonomy

The Space Shuttle systems and subsystems are expected to function properly without major refurbishment through at least 100 flights of the Orbiter and Booster. Normal system failures are anticipated, however, but no single point failure in any subsystem will interfere with the operational capability of either Orbiter or Booster. This is called fail operational. A two point failure can limit the operational capability of the vehicles, but will not jeopardize the safety of the crew. This is called fail safe. The onboard avionics system can detect and diagnose system failures on a sufficient level to automatically switch functions to working systems during all phases of the mission. The only exceptions to this system redundancy are structural failure and failure of one of the orbit (OMS) engines. In the reference design, two OMS engines can only provide fail safe capability for the deorbit maneuver.

In the event of an abort during the launch phase, the Orbiter will continue to the injection orbit and return to the launch site or alternative recovery site at the first opportunity. In the case of the Booster, the fail safe mode during ascent will permit early stage separation and propellant dumping prior to flyback. For the purposes of the OSS study, any failure which precludes these abort modes will be considered to have a sufficiently low probability of occurance.

The Orbiter and Booster are both capable of autonomous checkout and operation for prelaunch, launch, on-orbit and recovery, and only require interfaces with the ground for propellant loading and automatic landing aids at the landing site. Ground support equipment is required, however, during the ground turn-around cycle to detect and diagnose failures which are at a lower systems level than the onboard checkout system can identify.

Voice communication with the ground stations and ground tracking are provided for the purposes of flight confirmation and information. A data link is provided with the ground to transmit space shuttle systems status and experimental test data at the discretion of the crew and to receive ground status data (e.g., weather conditions, airways clearance and landing site conditions) on crew demand. A summary of the autonomy features is presented in Figure 3.

2.3 Propulsion Systems

2.3.1 Main Rocket Engines

There are 12 main rocket engines on the Booster and 2 on the Orbiter. The main rocket engines burn liquid hydrogen and liquid oxygen, and the same engine (power head) is used for both the Booster and Orbiter with the addition of a two position nozzle on the Orbiter main engine. The Orbiter engine nozzle is retracted during the first stage ascent, extended for second stage burn and then retracted for Orbiter reentry. The Booster main rocket engine dry weight is about 4600 pounds with a sea level thrust of 414,000 pounds as illustrated in Figure 4. The orbiter main engine weight is about 800 pounds more due to the larger nozzle and the nozzle extension and retraction mechanism.

2.3.2 OMS Engines

The Orbiter on-orbit maneuvering system (OMS) consists of two 15,000 pound thrust class, RL-10 type rocket engines using liquid hydrogen and liquid oxygen. The OMS system provides the propulsion for orbit transfers and the retro maneuver for reentry. The OMS system also provides a backup to the orbiter main engines in the event of two main engine failures during ascent. A safe ascent abort under OMS power could provide a once around orbit and reentry. The OMS propellants are stored in two liquid hydrogen and two liquid oxygen tanks that are separate from the main engine propellant tanks.

2.3.3 ACPS Engines

The attitude control propulsion system (ACPS) utilizes common thrusters in both the Orbiter and Booster. The ACPS provides three-axis attitude control for the Orbiter and Booster, and small on-orbit translation maneuvers for the orbiter. There are 22 thrusters on the Orbiter and 24 thrusters on the Booster each operating at a vacuum thrust rating of 1600 pounds. The ACPS propellants are stored in two independent sets of tanks.

2.3.4 Airbreathing Engines

Both the Booster and Orbiter employ airbreathing engines for subsonic operations. The Booster will cruise 355 nautical miles uprange to the launch site after separating from Orbiter, and the Orbiter and the Booster have the capability to abort a landing with sufficient go-around propulsion for a second approach. The go-around requirement for the Orbiter is receiving critical attention from the NASA and may be eliminated in favor of lower vehicle weights or additional payload capability for selected missions.

The airbreathing engines burn JP-4 propellant and are common to the Orbiter and Booster. In the baseline configurations, the airbreathing engines are low by-pass ratio JTF-22B type turbofans. Four turbofan engines are employed in the orbiter and eight in the booster.

2.4 Structures, Materials and Thermal Protection System

The basic load carrying structures for both the Orbiter and Booster vehicles are made of titanium alloy, similar to aircraft. The structural material for the main liquid hydrogen and liquid oxygen tanks is aluminum alloy with internal foam insulation. During the 100 mission operational life of the vehicles, it will not normally be required to refurbish, replace or rebuild any elements of these structures.

The thermal protection system (TPS), however, will require a certain degree of post flight inspection, non-destructive testing (NDT) and component replacement during the mission life of the main body vehicle. The TPS system is characterized by thin gage stand-off heat shield panels constructed of high temperature materials with high temperature insulation protecting the main body substructure. An estimate of the temperature distribution and representative TPS materials distributed according to thermal environment are illustrated in Figure 5. Typically, TPS refurbishment will be required to correct such defects as columbium coating degradation, micrometeor penetration, surface recessions due to oxidation and panel distortions due to material creep. NDT apparatus, spare materials and TPS panels would be maintained for use during post flight turn-around.

3.0 SPACE SHUTTLE MISSION CHARACTERISTICS

The primary design mission for the Space Shuttle is a nominal 7 day logistical resupply of an orbiting Space Station. The 7 days include the time from launch to return and landing (block to block). The round trip payload weight capability of the Space Shuttle is 25,000 pounds to the orbiting Space Station at 270 nautical miles, 55 degree inclination, and varies according to orbit altitude, orbit inclination, and launch site altitude. The payload weight includes all systems, containers and attachments necessary to support the payload in the Space Shuttle.

In the event of a space station emergency, the Space Shuttle can be launched from a ground standby status within about 4 hours of alert. The 4 hours prelaunch time is required for cryogenic propellant loading, crew and passenger loading, and terminal countdown. The Shuttle would launch, rescue the Space Station crew and return to the launch site within 48 hours. The hypersonic aerodynamic characteristic of the Shuttle Orbiter permit sufficient cross range maneuvering using roll modulation to limit the maximum wait time in orbit.

3.1 Alternate Mission Support

Other missions, in addition to Space Station logistics, will also be supported by the Shuttle, as illustrated by the table on Figure 6. These missions include manned and unmanned payloads for up to 30 days duration, and require the Orbiter to operate at any orbital altitude from 100 nm to 800 nm. The launch azimuth is not restricted,* so that the Shuttle will launch in the proper direction to arrive at the target orbit with maximum payload. The Shuttle will not operate into orbit inclinations less than the launch site latitude, however, due to the large payload sensitivities to plane change maneuvers.

The payload capability chart on Figure 7 is an estimate of the Space Shuttle oneway payload for unmanned satellite and planetary probe delivery when the Shuttle is launched from KSC. For the oneway mission the shuttle delivers the payload to orbit and returns at the next opportunity without the payload. The oneway payload is about 5,000 pounds higher than the round trip payload due to the lower weight that would exist during the deorbit maneuver.

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*An exception to this is the direct overfly of a high density metropolitan area. It may be necessary to restrict such overflies which are within about 200 miles of the launch site.

Launching the Shuttle from a launch site at a higher altitude than KSC will increase the payload to all orbits. The payload increase is about 1000 pounds per 1000 feet of altitude of the launch site.

4.0 SPACE SHUTTLE TRAJECTORY CHARACTERISTICS AND FLIGHT PROFILE

4.1 Ascent Phase

The mission profile and a typical Orbiter and Booster launch sequence is presented in Figures 8 and 9. The Booster main engines provide all the ascent propulsion through the first stage of flight up to stage separation. The Orbiter main engines are then started and inject the Orbiter plus payload into a 50 nm x 100 nm orbit. Following orbit insertion at 50 nm, the orbiter main engines are shutdown and the Orbiter coasts to the 100 nm apogee altitude. The two on-orbit maneuvering (OMS) engines are started at 100 nm and provide the necessary impulse to raise the orbit perigee to the target altitude or to a 100 nm phasing orbit if time phasing were required prior to the transfer maneuver to the target orbit. All on-orbit transfer maneuvers will be performed by the OMS engines.

4.2 Booster Reentry Phase

The Booster continues on an unpowered trajectory downrange following the stage separation. Using appropriate propulsive attitude control and aerodynamic roll control, the Booster makes a descending, turning maneuver until sufficient velocity is lost to start the airbreathing engines. The sequence is illustrated in Figures 8 and 9. The Booster then cruises back to the launch site under appropriate FAA flight rules.

4.3 Orbiter Reentry Phase

Prior to the deorbit maneuver, the Orbiter crew determines the reentry flight corridor necessary to arrive at the prime site or alternate sites as necessary. Flight corridor clearance is obtained from the ground and the reentry sequence is initiated. The Orbiter reentry is made directly from the operational orbit altitude and nominally does not require a phasing or propulsive plane change maneuver.

Two Orbiter reentry profiles are illustrated in Figure 10 for the 200 nm cross range and the maximum 1500 nm cross range maneuvers. The reentry interface occurs at 400,000 feet at a relative velocity of 25,134 feet per second. The total time from the deorbit at 270 nm altitude to the landing at the launch site is typically 2.76 hours for the low cross range and 3.25 hours for the high cross range reentry. The airbreathing engines are started prior to the final approach for landing to provide a go-around capability in the event of a wave-off.

5.0 SPACE SHUTTLE LAUNCH RATES AND TRAFFIC MODEL

The nominal time from landing to relaunch is two weeks (14 days). This applies to both the Orbiter and Booster. For the nominal 7 day mission the Orbiter launch to relaunch time is therefore about 21 days, and extends up to 44 days for the 30 day missions. The Booster missions, however, are typically under 2 hours duration so that the launch to launch time is about 14 days. Since any operational Orbiter in the Shuttle fleet can be mated with any operational Booster, 2 boosters are sufficient to support 3 orbiters. This ratio would be somewhat less dependent on the percentage of Orbiter missions greater than 7 days.

The total fleet size will vary with traffic requirements, production rates and spares. It is assumed that an operational Shuttle Orbiter can support 7 day missions at the rate of 17 flights/year and 30 day missions at the rate of 8 flights/year. Since the anticipated shuttle missions involve primarily short time missions, it is assumed that an operational Orbiter can support about 16 flights/year on the average. With a 2/3 ratio of Boosters to Orbiters, a Booster can support 24 flights/year. In addition to this, one Booster and one Orbiter will be on standby status at all times (i.e., 4 hours from launch ready) for space rescue mission.

The chart on Figure 11 presents a reference Space Shuttle traffic model prepared by the NASA Manned Spacecraft Center.[7] It is anticipated that the Space Station logistics and Department of Defense missions will require about 25 to 30 shuttle flights per year. The addition of unmanned satellites and planetary probes will increase the launch rate to about 52 per year including propellant launches for space based tug refueling. A space based tug is assumed to be included in this traffic model but the tug characteristics and necessary support are not defined.

A launch rate of 52 Space Shuttle flights per year (or one per week) will be used for baseline in the OSS study. An example of a launch schedule which could support this launch rate is presented in Figure 12. This launch schedule provides a four week standby for space rescue prior to each flight and is based on the nominal 7 day missions. Although 4 Orbiters and 4 Boosters would be sufficient to meet this schedule, no delay in the Orbiter availability is accounted for. To provide for some delays, 5 Orbiters would be necessary.

1013-DEC-klm

D.E. Cassidy

D. E. Cassidy

REFERENCES

1. Description of the Operational Support System Study - Case 900 Bellcomm Memo for File, J. J. Hibbert, June 5, 1970

2. A Proposal to Accomplish Phase B E0120, McDonnell Douglas Corp., March 30, 1970.

3. Proposal to Accomplish Phase B Space Shuttle Program, SD70-5 Space Division, North American Rockwell, March 27, 1970.

4. Space Shuttle Phase B Quarterly Review, McDonnell Douglas Corp., September 30, 1970.

5. Space Shuttle Phase B 90 Day Review, North American Rockwell, October 13, 1970.

6. Statement of Work, Space Shuttle System Program Definition (Phase B), National Aeronautics and Space Administration, February 1970.

7. NASA/DOD 25,000-Pound Space Shuttle Traffic Model - 1978 TD 1987 (U). MSC Internal Note No. 70-FM-178, November 2, 1970.

APPENDIX

SPACE SHUTTLE PROGRAM REQUIREMENTS

I INTRODUCTION

A. Purpose

The purpose of this document is to present the program requirements pertinent to the Phase B Study for the Space Shuttle Program. These requirements are the requirements established by the Director of the Space Shuttle Program that are necessary to achieve the objective of the Space Shuttle Phase B Study. This objective is to provide a low-cost, economical space transportation system.

All Space Shuttle Program planning and direction of NASA Centers should be in accord with the requirements stated herein unless specific exception is approved by the Director of the Space Shuttle Program.

II CHANGES

This document will be controlled according to the Space Shuttle Program Directive No. 1 dated July 1, 1970.

III RELATED DOCUMENTS

This document will be based on the Statement of Work, Space Shuttle System Program Definition (Phase B) dated February 1970. It is in accord with the Program Approval Document (PAD) dated April 28, 1970 as well as the Program Operation Plan (POP) and the Flight Mission Assignment Document (FMAD) when published.

LEVEL I - SPACE SHUTTLE PROGRAM REQUIREMENTS DOCUMENT

1. The shuttle shall be a reusable two (2) stage vehicle.

2. The cargo bay shall be sized to have a clear volume of 15' diameter by 60' length.

3. IOC baseline is the second half of 1977.

* 4. DELETED

5. The design reference mission is a logistics resupply of a space station or space base. Personnel and cargo transfer operations should nominally be accomplished in a single intra-vehicular operation. The design reference mission insertion orbit shall be 50 x 100 nautical miles, and the reference orbit shall be 270 nautical miles circular with a 55^{o} inclination. For purposes of performance comparison calculations the vehicle shall be considered to be launched from a latitude of 28.5^{o} North. Table 1 contains a general description of the mission and mission requirements that have been identified as being of major interest in future space program planning.

6. The orbiter (s) shall have a nominal hypersonic aerodynamic cross-range capability of:

   a. Approximately 200 NM

   b. Approximately 1500 NM

* 7. DELETED

* 8. Mission duration (from lift-off to landing) of 7 days of self-sustaining lifetime shall be provided. For missions in excess of 7 days the weight of the expendables shall be charged against the payload.

9. The Space Shuttle shall be capable of operating within the cargo range from zero to maximum capability.

10. The orbiter shall have sufficient propellant to provide 1,500 fps on-orbit Δ V capability (in excess of amount required to attain the design reference mission insertion orbit) with a maximum payload. The tanks shall be sized to provide 2,000 fps Δ V capability.

11. The booster and orbiter shall be baselined to have go-around capability.

12. The booster and orbiter crew and the orbiter passengers environment shall be shirtsleeve.

13. The booster shall be capable of returning to the launch site.

14. All vehicle stages shall be capable of ferry flights between airports.

15. Integrated vehicle vertical takeoff and individual vehicle horizontal landing shall be the vehicle mode of operation.

16. A communication satellite system is assumed to be available.

17. Launch rates will vary from a minimum of 25 to a maximum of 75 per year.

18. The space shuttle shall have an all-azimuth launch capability.
19. The shuttle shall provide safe mission termination capability. This includes rapid crew and passenger egress prior to liftoff and intact abort after liftoff. Intact abort implies the capability of the booster and orbiter to separate and continue flight to a safe landing; the orbiter to land with a full payload.
20. 400,000 pound sea level thrust bell-type engines will be baselined in both the orbiter and booster stages.
21. The intended combined storage and operational service life of this system is 10 years after IOC. A booster/orbiter life of 100 missions will be provided with a cost effective level of refurbishment and maintenance.
22. For the design reference mission rescue operations (including personnel transfer) must be completed within 48 hours after notification.

*23. Hydrogen will be baselined as fuel for all airbreathing engines.

24. All subsystems except primary structure and pressure vessels shall be designed to fail operational after the failure of the most critical component and to fail safe for crew survival after the second failure. Electronic systems shall be designed to fail operational after failure of the two most critical components and to fail safe for crew survival after the third failure. Individual subsystems may be revised by Level II decision where improvements in cost and effectiveness would result.

* Change to JP4 fuel for all airbreathing engines.

25. Survivability against hazards from radiation as specified in Joint DOD/NASA Survivability Characteristics document (s) dated 16 June 1969.

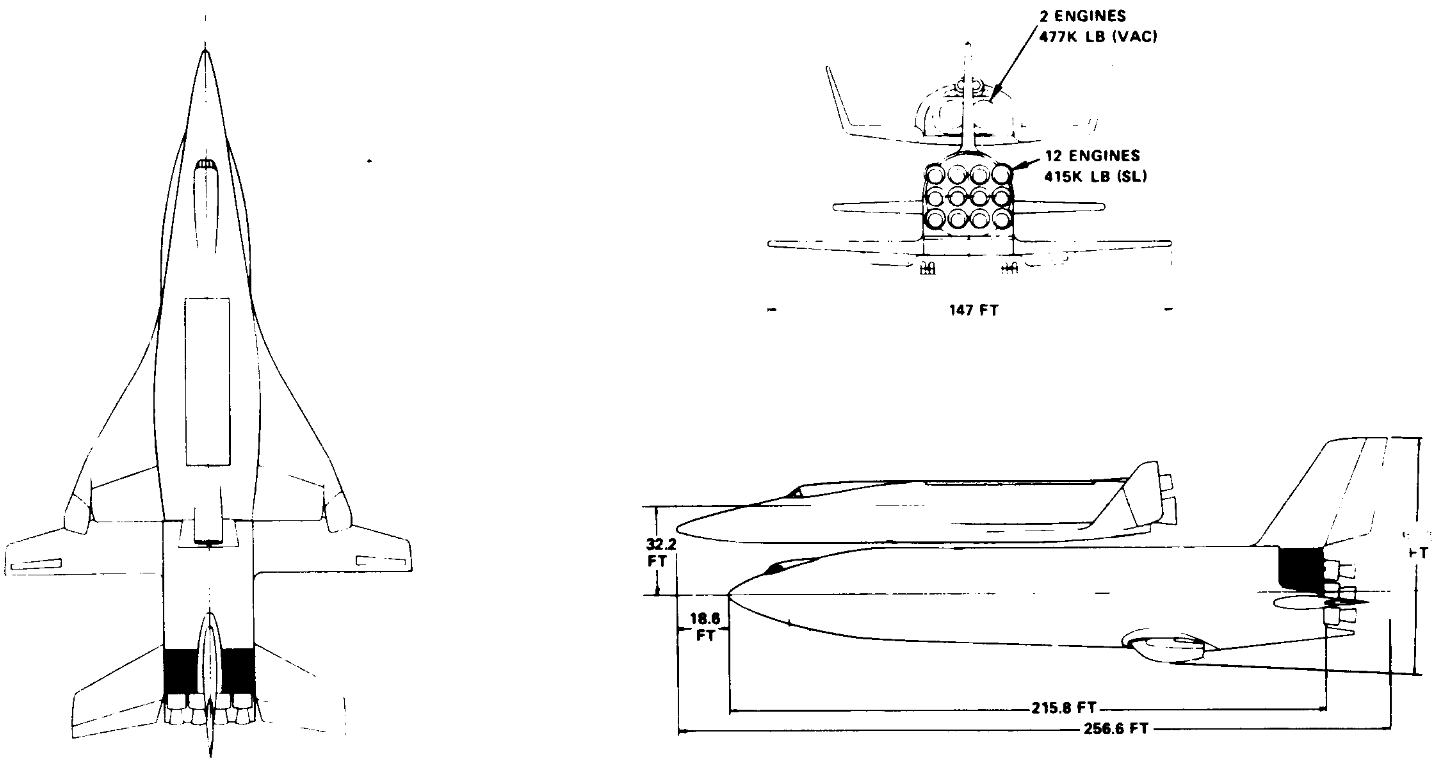
26. Total space shuttle turn around time from landing to launch readiness should be less than two weeks. The removal and replacement time shall be minimized with on-board checkout and module accessibility.

27. The vehicle trajectory load factors should not exceed 3g for passenger-carrying missions.

28. The space shuttle crew/passengers compartment atmosphere and total pressure shall be compatible with the space station and space base.

* 29. Vehicle payload is baselined to be 25,000 pounds into the design reference orbit (270 NM 55° inclination). Vehicle design requirements shall be based on resulting payload capability for an easterly launch into a 100 NM orbit.

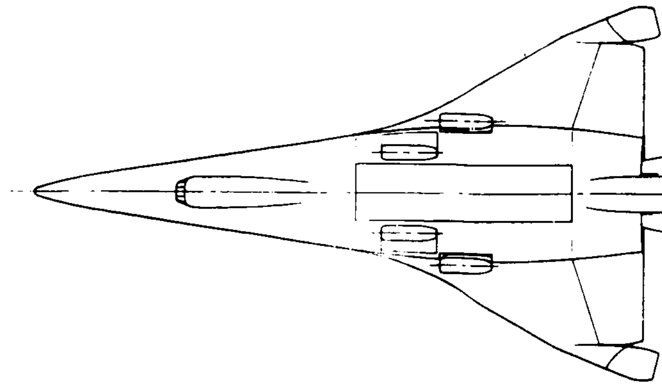
*Changes this date



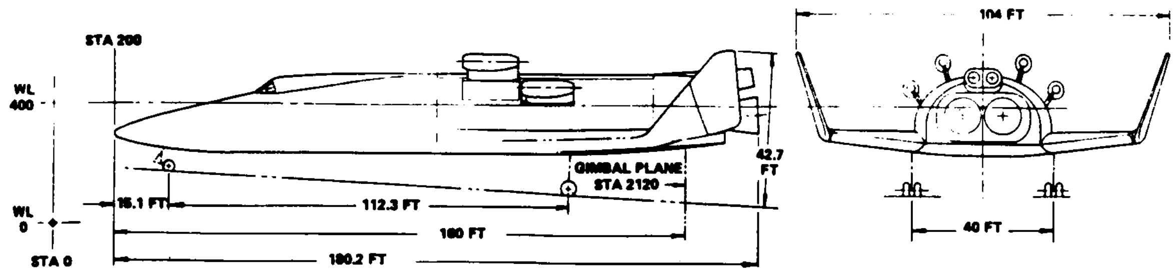
ORBITER:		(POUNDS)
GROSS LIFT OFF WEIGHT	–	650,000
TOTAL [illegible] WEIGHT	–	62,000
[illegible] WEIGHT	–	370,000
[redacted]		
[illegible] OFF WEIGHT	–	3,330,000
[illegible] WEIGHT	–	395,000
[illegible] EIGHT	–	2,370,000
TOTAL J[illegible] [redacted]	–	85,000
LANDING W[illegible] [redacted]		

FIGURE 1. MATED VEHICLE SYSTEM–DELTA WING
ORBITER & BOOSTER

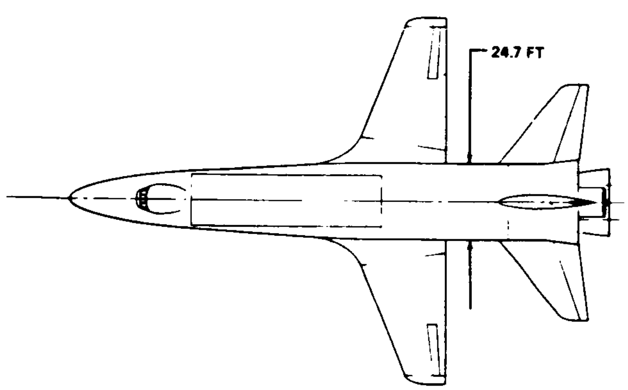
ORBITER, DELTA WING



GROSS WT = [illegible] LB	
CONFIGURATION	INTEGRAL LH_2 TANK, FLOATING LO_2 TANK: LOW WEIGHT
AERO/THERMAL	ENTRY L/D: 0.7 - 2.4 SUB L/D: 9.1 $W/C_L S$: 48 LB/FT^2
STRUCT/TPS	PRIMARY TITANIUM TANKS: ALUMINUM HEAT SHIELD: RADIATIVE
SYSTEMS	MAIN 2 X 477KLB ENGS; OMS (2 X RL 10) ACPS: SUPERCRITICAL STORAGE O_2-H_2 ABES 4 X JTF 22B-JP FUEL



ALTERNATE ORBITER, STRAIGHT WING



GROSS WT = 675,000 LB	
CONFIGURATION	FLOATING TANKS
AERO/THERMAL	ENTRY L/D: 0.56 SUB L/D: 8.3 $W/C_L S$. FWD CG 54.3 LB/FT^2 AFT CG 47.0 LB/FT^2
STRUCT/TPS	PRIMARY: TITANIUM TANKS: ALUMINUM HEAT SHIELD: RADIATIVE
SYSTEMS	MAIN 2-477 KLB ENGS; OMS - 2XRL-10 ACPS: SUPERCRITICAL. H_2-O_2 ABES - 4 X JTF-22B-JP FUEL

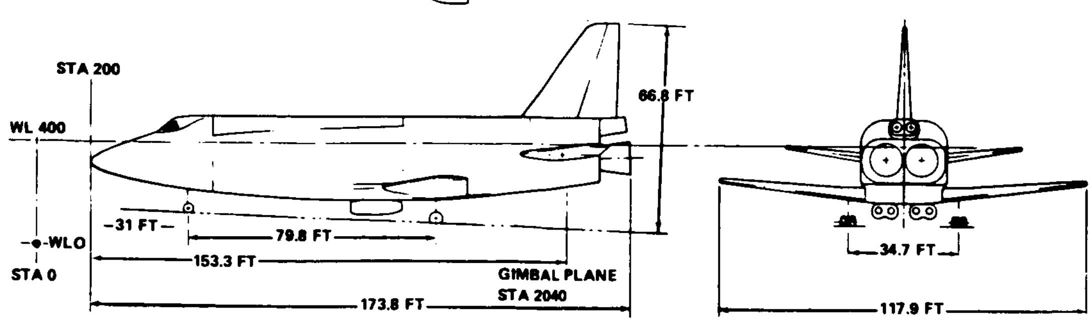
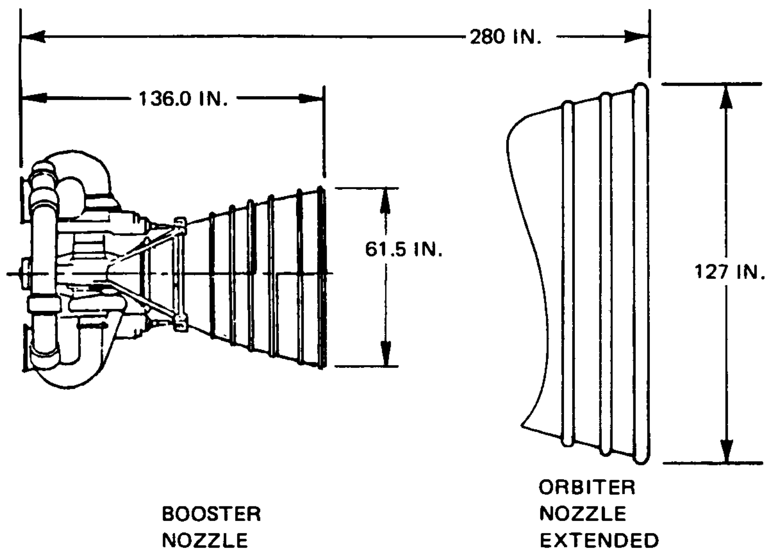


FIGURE 2

MISSION PHASE	SPACE SHUTTLE INTERFACE WITH GROUND
TURN AROUND & MAINTENANCE	COMBINATION OF ONBOARD & AGE CHECKOUT & DIAGNOSIS
PRE LAUNCH	• VOICE COMMUNICATIONS • PROPELLANT TRANSFER
LAUNCH & ASCENT	• VOICE COMMUNICATIONS • TRACKING FOR FLIGHT CONFIRMATION & INFORMATION
ON ORBIT	• VOICE COMMUNICATIONS • TRACKING FOR FLT. CONFIR. & INFO. • UP LINK GROUND STATUS DATA • UP LINK FLIGHT REFERENCE DATA • DOWN LINK COMPUTER STORED SYSTEM STATUS DATA DUMPED ON SHUTTLE COMMAND • DOWN LINK EXPERIMENT DATA (FOR ALTERNATE SHUTTLE MISSIONS)
RECOVERY & LANDING	• VOICE COMMUNICATIONS • TRACKING FOR FLT. CONFIR. & INFO. • AUTOMATIC LANDING ELECTRONICS AT PRIME SITE & SELECTED ALTERNATE SITES (PREFER MILITARY)

FIGURE 3. SPACE SHUTTLE AUTONOMY FOR THE PURPOSES OF THE BELLCOMM OPERATION SUPPORT SYSTEM STUDY

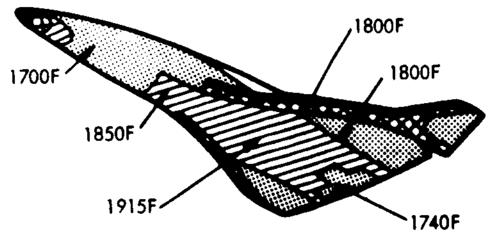


BOOSTER INSTALLATION

SEA LEVEL THRUST	414,000 POUNDS
GIMBAL ANGLE	±10 DEGREES
OPERATIONAL LIFE	7.5 HOURS
NUMBER OF STARTS	100
WEIGHT WITHOUT NOZZLE	
EXTENSION DRY	4583
WET	4888

FIGURE 4. MAIN BOOST PROPULSION ENGINE

HIGH CROSS RANGE
(1500 NMI)



TPS MATERIAL	HIGH CROSS RANGE	
	AREA (FT^2)	WT (LBS)
METALLIC SHIELD	(14944)	(31610)
RPP	289	1230
C_b 752	1122	2658
TD N_1 Cr	2182	5020
SUPER ALLOY	9975	22702
INSULATION		(13170)
TANK INSULATION		(1745)
TOTAL		46525

(BOOSTER)

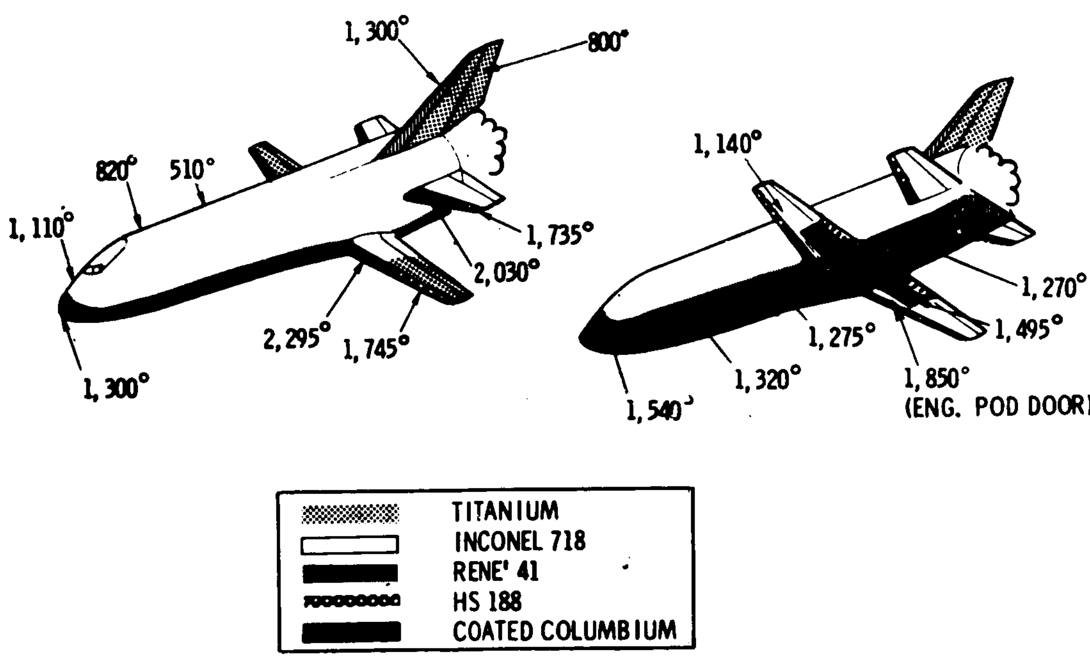


FIGURE 5. THERMAL PROTECTION SYSTEM

ORBITAL CHARACTERISTICS / MISSIONS	SPACE STATION/ BASE LOGISTICS SUPPORT	PLACEMENT AND RETRIEVAL OF SATELLITES	DELIVERY OF PROPULSIVE STAGES & PAYLOAD	DELIVERY OF PROPELLANTS	SATELLITE SERVICE & MAINTENANCE	SHORT DURATION ORB. MISSION
ALTITUDE (N. MI.)	200 - 300	100 - 800	100 - 200	200 - 300	100 - 800	100 - 300
INCLINATION (DEG.)	28.5-90	28.5-SUN SYN.	28.5-55	28.5-55	28.5-SUN SYN.	28.5-90
ON-ORBIT ΔV (1000 FPS)	1 - 2	1 - 5	1 - 1.5	1 - 2	1 - 5	1 - 2
ON-ORBIT STAY TIME (DAYS)	7	7	7	7	7 - 15	7 - 30
CREW	2	2	2	2	2	2
PASSENGERS (MIN.)	ROTATE 50 MEN/QTR	2	2	2	4	12
DISCRETIONARY PAYLOAD						
WEIGHT (1000 LBS.)	*70/QTR	-------------	-------------	-----------	-----------	-----------
VOLUME (1000 FT.^{3})		5 - 10	10	10	5 - 10	4 - 6
CRITICAL DIMEN. DIA. (FT.)	10 - 15	15	15	15	15	15

* INCLUDE PASSENGERS

FIGURE 6. MISSION CHARACTERISTICS

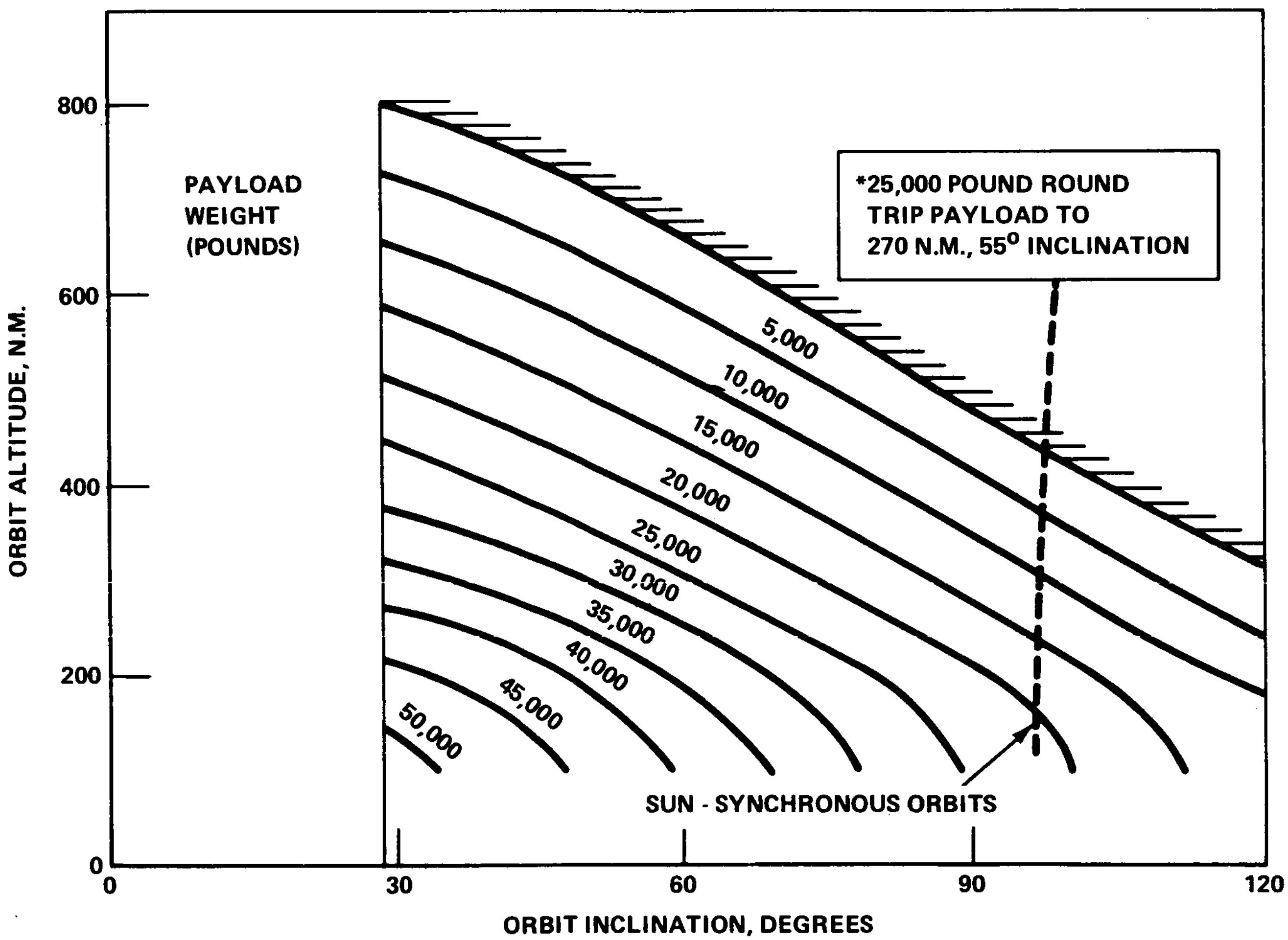
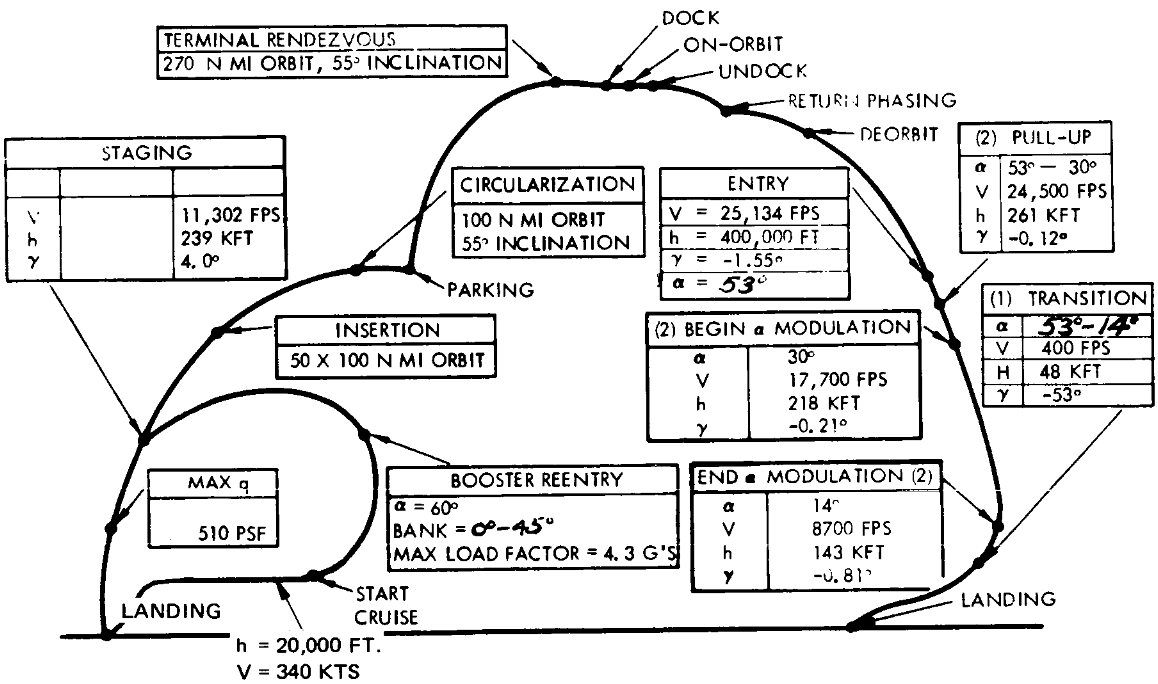


FIGURE 7. ESTIMATED PAYLOAD ONE-WAY CAPABILITY OF A 25,000 POUND PAYLOAD* SPACE SHUTTLE—DIRECT INJECTION, DIRECT DEORBIT



(1) 200 N.M. CROSS RANGE MISSION
(2) 1500 N.M. CROSS RANGE MISSION

FIGURE 8. BASELINE REFERENCE MISSION

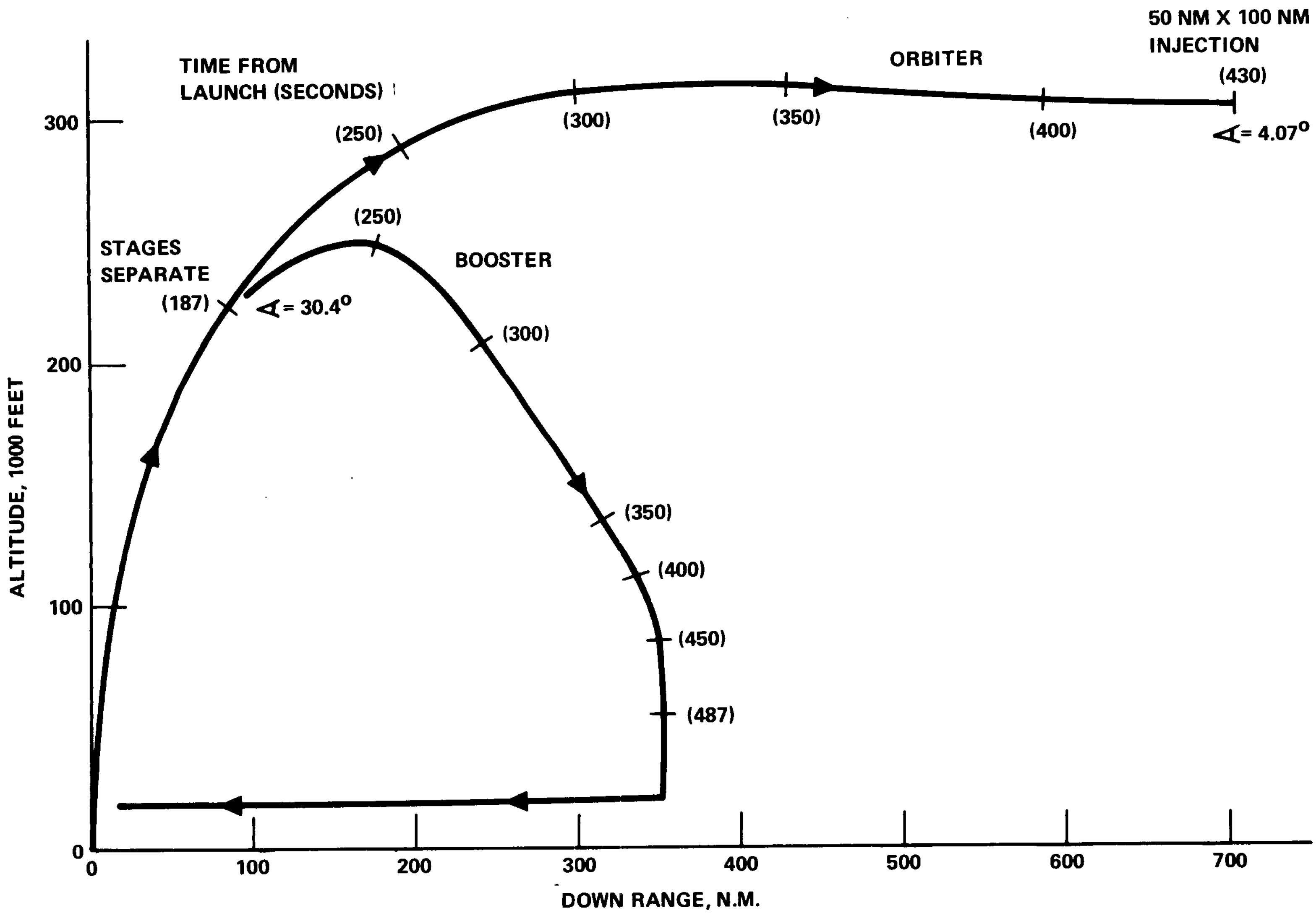
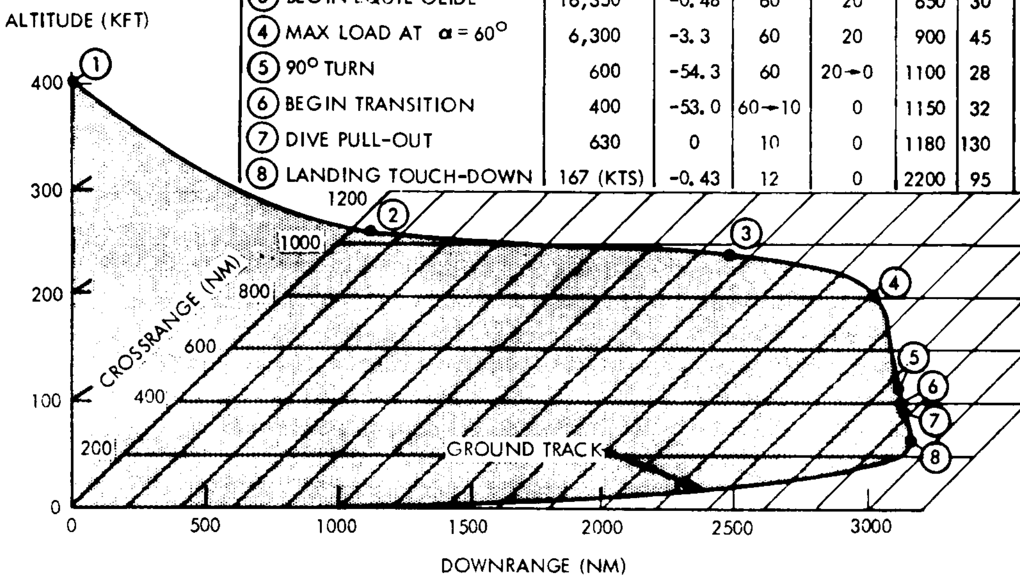


FIGURE 9. NOMINAL LAUNCH TRAJECTORIES & BOOSTER FLYBACK

ENTRY FLIGHT PROFILE FOR 200 N MI CROSS-RANGE

EVENT	V_R (FPS)	γ_R (DEG)	α (DEG)	ϕBANK (DEG)	t (SEC)	$\bar{q}$ (PSF)	N (G's)	h
(1) ENTRY	25,134	-1.55	60	0	0	0	0	400,000
(2) PULL-UP (MAX TEMP)	24,350	-0.10	60	0→83	275	13	0.49	260,000
(3) BEGIN EQUIL GLIDE	16,350	-0.48	60	20	650	30	1.16	222,000
(4) MAX LOAD AT $\alpha = 60^\circ$	6,300	-3.3	60	20	900	45	1.69	161,000
(5) 90° TURN	600	-54.3	60	20→0	1100	28	1.12	65,000
(6) BEGIN TRANSITION	400	-53.0	60→10	0	1150	32	1.05	50,000
(7) DIVE PULL-OUT	630	0	10	0	1180	130	1.96	38,000
(8) LANDING TOUCH-DOWN	167 (KTS)	-0.43	12	0	2200	95	1.0	0



ENTRY FLIGHT PROFILE FOR 1500 N MI CROSS-RANGE

EVENT		h (FT)	V (FPS)	γ (DEG)	α (DEG)	ϕ(BANK) (DEG)	t (SEC)	q (PSF)	N(g's)
ENTRY	(1)	400,000	25,134	-1.55	53	0	0	0	0
PULLUP/PITCHDOWN	(2)	261,000	24,507	-0.12	53→30	0→68	271	12	0.46
BEGIN α MODULATION	(3)	218,000	17,712	-0.21	30	35	1120	42	0.70
END α MODULATION	(4)	143,000	8,721	-0.81	14	15	1920	176	0.92
MAX g	(5)	107,000	4,133	-1.75	14	15	2304	205	1.07
90° TURN	(6)	102,000	3,676	-1.88	14	15→0	2342	201	1.05
TURBOFAN IGNITION	(7)	40,000	655	-6.3	10	0	2992	126	1.0
LANDING	(8)	0	160 (KTS)	0	17	0	3968	87	1.0

DEORBIT TO 400,000 FT. (BOTH CASES)

β = 129 DEG.
R = 7746 NM.
t = 1977 SEC.

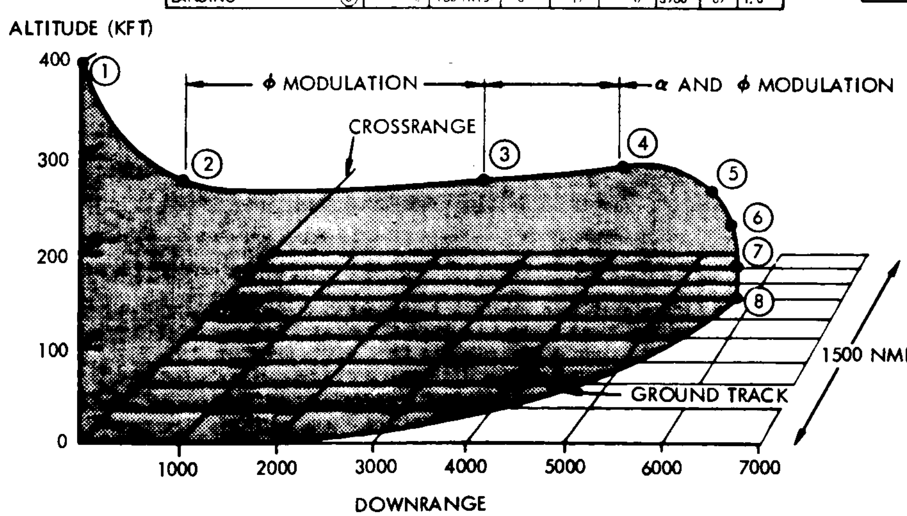


FIGURE 10

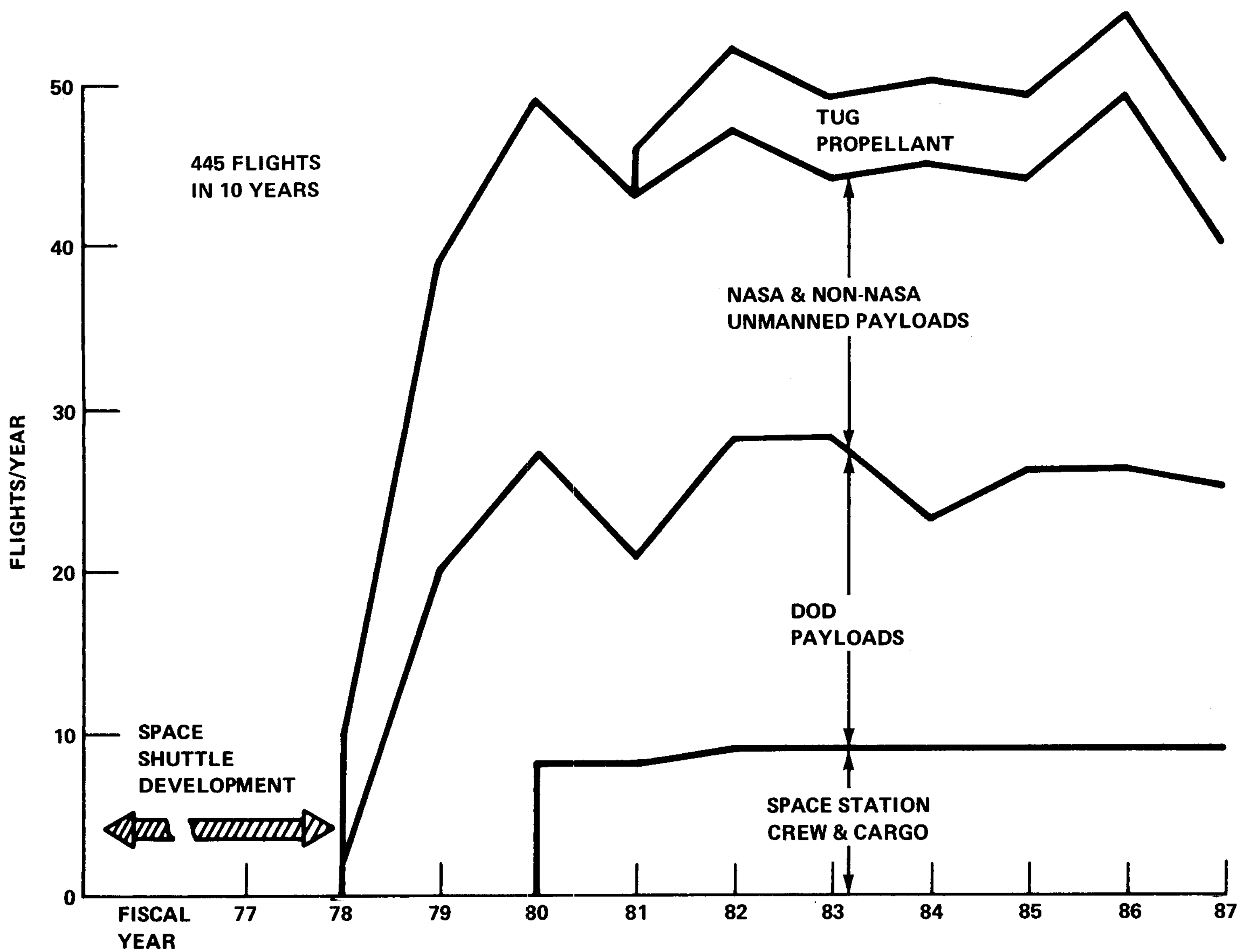


FIGURE 11. SPACE SHUTTLE TRAFFIC MODEL

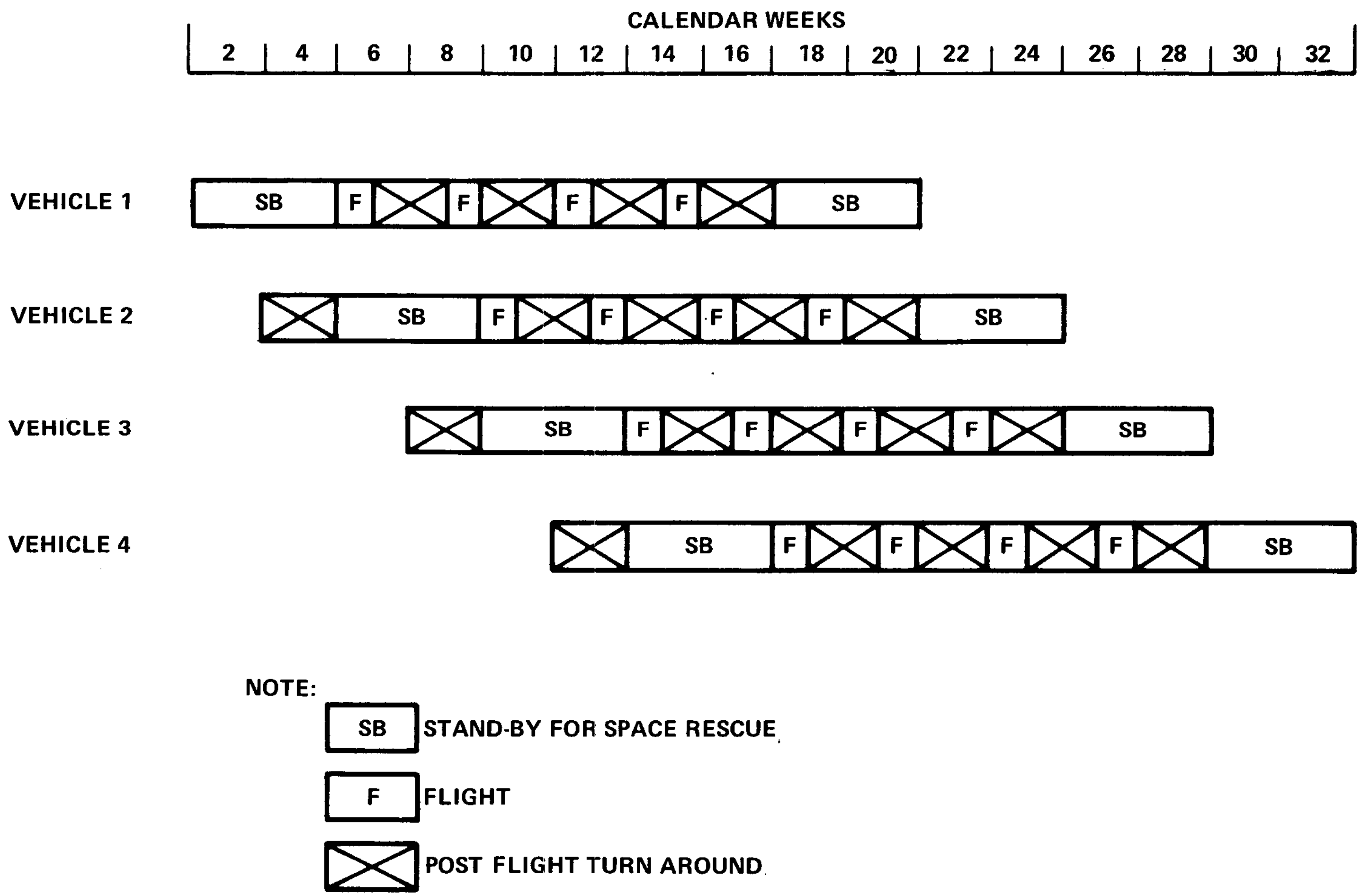


FIGURE 12 - FLIGHT SCHEDULE OPTION FOR NOMINAL 7-DAY MISSIONS

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